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Interim Letter XI

Paul Krell, President
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705 North Mountain Road, Suite A211
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Dear Mr. Krell:

I have included a copy of a paper submitted to the scientific journal 'American Journal of Industrial Medicine.' The paper was recently accepted for publication and will be accessible in print sometime during 2011. The results included in the paper are from 97 employees who participated in both the 2002 and 2005 medical surveys at the 25 Sigourney Street building.

The major findings of the paper follow:

1. In general, we observed no overall improvement in respiratory health over the three-year period, as reflected in symptom scores, overall medication use, spirometry abnormalities, or sick leave among this group of 97 employees.

2. Some persons developed new abnormal lung function by the 2005 survey. Four employees went from borderline bronchial hyper-responsiveness to bronchial hyper-responsiveness, six developed abnormal spirometry, three more reported post-occupancy physician-diagnosed current asthma, and four physician-diagnosed hypersensitivity pneumonitis.

3. However, a subset of employees improved in some health status indices. Respiratory cases (in 2002), as a group, reported significantly less oral steroid use in 2005. In addition, 2002 respiratory cases that relocated within the building reported both a decrease in medication use and sick leave in 2005.

If you have any questions regarding the information provided in this interim letter, please do not hesitate to contact us at 1-800-232-2114.

Sincerely,

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Lack of Respiratory Improvement Following Remediation of a Water-Damaged Office Building

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Background *Damp buildings are commonly remediated without removing employees or ongoing medical surveillance.*
Methods *We examined paired pulmonary function and questionnaire data from 2002 and 2005 for 97 employees in a water-damaged building during ongoing but incomplete remediation.*
Results *We observed no overall improvement in respiratory health, as reflected in symptom scores, overall medication use, spirometry abnormalities, or sick leave. Four employees went from borderline bronchial hyperresponsiveness to bronchial hyperresponsiveness; six developed abnormal spirometry; three more reported post-occupancy current asthma, and four hypersensitivity pneumonitis. The number of participants without lower respiratory symptoms decreased from 27 in 2002 to 20 in 2005. Respiratory cases relocated in the building had a decrease in medication use and sick leave in 2005.*
Conclusions *During dampness remediation, relocation may be health protective and prevent incident building-related respiratory cases. Without relocation of entire workforces, medical surveillance is advisable for secondary prevention of existing building-related disease.* Am. J. Ind. Med. *© 2010 Wiley-Liss, Inc.*

KEY WORDS: dampness; asthma; hypersensitivity pneumonitis; healthy worker effect; building-related illness

INTRODUCTION

In 2001 the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation of a 20-story office building, which was known to have recurrent water damage since occupancy by its current tenants in 1994 [Cox-Ganser et al., 2005; Park et al., 2006, 2008]. Prior to 2001, environmental surveys by several consultants revealed water incursion through the roof, around windows, and under sliding doors from balconies, with exacerbation of water intrusion through the building envelope by a negative pressure gradient indoors compared to outdoors. In addition, plumbing leaks had damaged interior walls. From 1995 to July 2001, 60 employees filed workers' compensation claims for building-related health conditions.

During our 2001 questionnaire survey, we found that the incidence of adult-onset asthma among participating office workers was 7.5 times higher after building occupancy than prior to occupancy [Cox-Ganser et al., 2005]. NIOSH investigators found statistically significant increased prevalence ratios for wheezing (2.5), lifetime asthma (2.2), current asthma (2.4), adult-onset asthma (3.3), and respiratory symptoms improving away from work (3.4) when compared with the U.S. adult population. We identified a five-person cluster of cases with post-occupancy physician-diagnosed hypersensitivity pneumonitits and three cases of physician-diagnosed post-occupancy sarcoidosis [Cox-Ganser et al., 2005]. An exposure–response relationship existed between

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physician diagnoses of asthma and HP along with dates of diagnoses; asthma emergency room visits; smoking history; and work history in the building.

We defined LRS as wheeze/whistling in the chest, chest tightness, shortness of breath, and cough occurring in the last 4 weeks. We constructed a LRS point scale as the frequency and number of LRS occurring in the last 4 weeks, with a possible range from 0 to 16. We defined work-related LRS as symptoms occurring at least two to three times a week in the last 4 weeks and reported to improve away from work. Systemic symptoms were defined as the presence of fever, chills, night-sweats, flu-like achiness, or unusual tiredness or fatigue that occurred weekly or daily in the last 4 weeks. We defined post-occupancy current asthma as asthma reported as diagnosed by a physician and still present, with a date of diagnosis at or after occupancy in the building. We defined medication use with a point scale based on respiratory oral, inhaler, or non-prescription medications, with a possible range from 0 to 24. This medication scale did not include antihistamines for upper respiratory complaints.

Medical Tests

Pulmonary function testing in 2005 was identical in procedures to 2002 testing [Cox-Ganser et al., 2005]. In brief, we measured forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1) using a volume spirometer (SensorMedics Spirometer, Yorba Linda, CA) and calculated the FEV_1 to FVC ratio. We defined an abnormal test result as being at or below the lower limit of normal [Hankinson et al., 1999], and we characterized abnormal test results as having patterns of restriction, obstruction, or both [American Thoracic Society, 1995]. To detect bronchial hyperresponsiveness (BHR), we performed methacholine challenge testing using standardized techniques [Crapo et al., 2000] with 0.125, 0.5, 2, 8, and 32 mg/ml methacholine. We calculated the provocative concentration of methacholine that causes an interpolated 20% decline in FEV_1 from the baseline (PC_{20}). We defined BHR as a PC_{20} of $\leq$4.0 mg/ml and borderline BHR as a PC_{20} between 4.1 and 16.0 mg/ml [Crapo et al., 2000]. In subjects with baseline $FEV_1 < 70\%$ of the predicted value, we tested for reversible bronchoconstriction with a bronchodilator, using a criterion of a 200 ml and 12% increase in FEV_1.

Data Analysis

To assess the possibility that our study participants might reflect a healthy worker survivor effect, we compared health characteristics between participants (Group A) versus those who left employment (Group B1) and the non-participants who stayed in the building (Group B2). We tested for differences in 2002 health status between participants and non-participants by using non-parametric Wilcoxon rank-sum analyses for the continuous variables and chi-square tests for the categorical variables.

To assess the effect of the remediation intervention on respiratory health, we examined 2002 and 2005 questionnaire and pulmonary test data for the 97 persons in the cohort, as well as by the 2002 subgroups of respiratory cases and non-cases. To assess the effect of relocation within the building, we compared paired results from 2002 and 2005 for the relocated group of respiratory cases and the non-relocated respiratory cases.

We used SAS® software (version 9.2, SAS Institute, Inc., Cary, NC) to analyze the data. We used a probability level of $P \leq 0.05$ as a criterion of statistical significance, and $0.05 < P \leq 0.10$ as being marginally significant. To examine time trends, we compared 2002 and 2005 results using paired t-tests for continuous variables and McNemar's test for categorical variables. We used SAS® PROC MIXED to examine time trends between respiratory cases and non-cases for continuous variables and SAS® PROC GENMOD for categorical variables. We also used these procedures to study the effect of relocation for respiratory cases. The categorical variables included cases of abnormal spirometry, BHR, breathing medication use, and physician-diagnosed post-occupancy current asthma. The continuous variables included mean changes in the spirometry results (% predicted FVC, % predicted FEV_1, FVC/FEV_1 ratio), sick leave days, and point scales for LRS and medication use.

RESULTS

Characteristics of Study Cohort

The 97 participants had worked in the building for an average of 6.8 years (range: 0.7–8.0 years) in 2002; had a mean age of 47.0 years; and were 64% female (Table I). Most were never smokers (67%). In 2002, 54 (56%) were classified as respiratory cases and the remaining 43 as non-cases. In 2005, 51 (53%) were classified as respiratory cases. Many of the non-cases, while not meeting the respiratory case definition by frequency and number of symptoms or physician diagnoses, had symptoms in 2002: over one-third (16/43) had LRS, 21% (9/43) had systemic symptoms, and only about one-half had no lower or systemic symptoms (53%). Of the 97 participants, 81 participated in spirometry testing and 63 had methacholine challenge or bronchodilator testing in both 2002 and 2005.

Those 2002 participants who had left employment were significantly older and more likely to have ever smoked (never smokers, 48%) when compared to cohort study participants (Table I). They did not differ significantly from participants in building tenure or gender. They had a significantly lower mean percent predicted FVC. In addition, many of their other indices of respiratory health were worse, although not significantly so.

2005 survey. Among the four cases, the range of respiratory sick leave varied widely (range: 4–110 days). One of the cases had relocated within the building. None reported home dampness.

Medical test results were also dynamic. In 2002, two participants had BHR, but no test results were available for these people in 2005. Four employees with borderline BHR in 2002 developed BHR in 2005. Of the eight employees with abnormal spirometry results in 2002 that also had 2005 results available, one person with mild obstruction had normal spirometry in 2005. Three participants developed obstruction and three participants developed restriction in 2005. In summary, the number of employees in the cohort who had abnormal pulmonary function tests increased from 8 in 2002 to 13 in 2005.

Interval Changes in Health by Respiratory Case Status

Both respiratory case and non-case groups in the 2002 cohort changed little over the 3-year interval (Table II). As a group, respiratory cases used less oral steroids in 2005. Nine of the 54 respiratory cases improved such that they no longer met the case definition in 2005, while six 2002 non-cases met the respiratory case definition by 2005. There were no significant differences in the time interval change for health outcomes between the respiratory case and non-case groups, with the exception of abnormal spirometry which increased in the non-case group (0–11%) but stayed relatively stable for the respiratory case group. Among the 2002 non-case group, the number of persons without LRS shrank from 27 in 2002 to 20 in 2005. Among the newly symptomatic was one new HP case. The 2002 non-case group as a whole had a significant decrease in mean FEV_1/FVC ratio in 2005 (Table II).

When we stratified the entire cohort (both respiratory cases and non-cases) by use of breathing medication, persons who did not take any breathing medication in 2002 had a significant decrease in mean FEV_1/FVC ratio and increase in medication use in 2005 ($P < 0.05$). They also were more likely to have abnormal spirometry, BHR, or LRS in 2005 ($P < 0.10$). Those that did take medication in 2002 took significantly less in 2005, including a large decrease in the use of oral steroids (data not shown).

Interval Health Effects of Relocation Intervention

There were three persons that relocated from an outside building back to the building between the 2002 and 2005 surveys. One person who returned to the building in 2004 was diagnosed with HP that same year. This person had a worsened health status after returning to the building, as indicated by breathing medication use and LRS in the 2005

TABLE II. Mean Change in Health Characteristics From 2002 to 2005 Among Surveys Participants by 2002 Group Assignment (Respiratory Cases, Non-Cases) Using Only Paired Data

	Respiratory cases (2002, N = 54)		Non-cases (2002, N = 43)	
Health characteristic	**2002**	**2005**	**2002**	**2005**
Bronchial hyperresponsiveness or positive bronchodilator test, % (n)	0	6.7% (2)	0	6.1% (2)
FVC % predicted	96.1%	95.5%	100.8%	101.9%
FEV_1% predicted	93.6%	92.7%	99.9%	99.7%
FEV_1/FVC ratio	**78.1%***	**77.2%***	**79.0%****	**77.4%****
Abnormal spirometry, % (n)*	18% (8)	20% (9)	**0****	**11% (4)****
LRS point scale, mean (SD)	5.7 (3.6)	5.7 (3.8)	**0.9 (1.4)***	**1.5 (2.4)***
Work-related LRS, % (n)	51.9% (28)	50.0% (27)	7.1% (3)	16.7% (7)
Medication use scale, mean (SD)	1.7 (2.8)	1.1 (2.1)	0.2 (0.7)	0.3 (1.2)
Oral steroid use (last 12 months), % (n)	**22.2% (12)****	**7.4% (4)****	4.7% (2)	0
Inhaled steroid use (last 4 weeks), % (n)	14.8% (8)	13.0% (7)	2.3% (1)	2.3% (1)
Beta-agonist use (last 4 weeks), % (n)	22.2% (12)	22.2% (12)	0	7.0% (3)
Post-occupancy current asthma, % (n)	33.3% (18)	37.0% (20)	0	2.3% (1)
Sick leave days (respiratory), mean (SD)	4.6 (6.4)[a]	6.3 (15.6)[b]	2.9 (9.6)[c]	2.0 (5.7)[d]

LRS, lower respiratory symptoms.
In bold: Health characteristic for which group (case vs. non-case) effect in individual interval changes from 2002 to 2005 was significant (health characteristic bolded); or the change from 2002 to 2005 within a group was significant (value bolded). Results after excluding an outlier who missed 110 days due to respiratory symptoms in 2005 are given as: [a]4.2 (5.6), [b]4.3 (6.2). Results after excluding an outlier who missed 60 days due to respiratory symptoms in 2002 are given as: [c]1.5 (3.2), [d]1.6 (5.0). Due to small numbers, we were unable to conduct significance testing for time interval change between cases and non-cases on oral steroid use, beta-agonist use, and post-occupancy current asthma.
*$P \leq 0.10$.
**$P \leq 0.05$.

2002 suggests that the incidence ratio for asthma is about 6.7 times expected over the 3-year remediation interval, in comparison to an expected incidence of about 1.9 per 1,000 person-years. Objective measures of paired pulmonary function and BHR tests substantiated deteriorating overall health status, as indicated by an overall decrease in FEV_1/FVC and new BHR in four persons. No objective pulmonary function measure documented significant improvement in this population. Although lack of improvement might be due to insufficient time for improvement in building-related lung disease, this interpretation is undermined by the occurrence of new disease, implying continuing hazard.

The four new cases of HP reported since the initial survey in 2002 resulted in a cumulative prevalence of nine cases among 248 participants (3.6%), with the possibility that additional incident cases occurred in the non-participating workers. This prevalence is not unusual among occupants of buildings in which HP cases have been recognized. Environmental scientists have not compared environmental exposure characteristics in damp buildings with and without HP cases. A sentinel case of HP usually is accompanied by building-related asthma cases and high prevalences of respiratory symptoms among co-workers, suggesting an overlap of health outcomes with dampness-associated exposures. None of the participants with incident diagnoses of HP reported home dampness or bird exposures as alternative environmental causes.

Despite the expenditure of 7.5 million dollars by 2004, the intended improvement in occupant health did not occur for all of the 97 employees. There are at least three possible explanations that merit consideration. First, is it possible that the increased respiratory morbidity among these building occupants was not related to dampness-related exposures and hence not likely to be affected by dampness remediation? A number of observations make this unlikely. The building occupants in 2001 reported asthma onsets before building occupancy that resulted in a normal incidence rate during adulthood; this rate increased 7.5-fold after occupancy until 2001 and continues in this small cohort at a similar rate from 2002 until 2005. HP is a rare disease, and the clusters in this building both before 2002 and between 2002 and 2005 suggest a common cause from continued dampness-related exposures. The temporal occurrence of respiratory symptoms in relation to the work day suggests building-related causative exposures. The improvement of a subset of respiratory cases with relocation outside the building and within it suggests a causal association with building-related exposures. The correlation of objective measurements with case and non-case status based on symptoms minimizes any psychological explanation for this morbidity, which in any case does not meet diagnostic criteria for mass psychogenic illness in its symptoms, lack of a chain of transmission, and endemicity over many years.

Second, is it possible that remediation was adequate but occupants with respiratory illness might not improve? Indeed there is considerable information in the literature that suggests that recovery from damp building-related respiratory illness is incomplete and delayed. Patovirta et al. [2004] did not find respiratory symptom improvements 1 year after remediation, nor did Jarvis and Morey [2001] 4 months after occupants were relocated to a dry building. The latter investigators did document cross-sectional improvements in chest tightness, shortness of breath, and cough approximately 4 years later before re-occupancy of the remediated building. However, the prevalences of those symptoms, as well as wheezing, were still double the prevalences found in the comparison population. Haverinen-Shaughnessy et al. [2004] demonstrated that post-remediation prevalence of respiratory symptoms decreased in students studied cross-sectionally in schools followed up to 5 years after repairs, but that students participating in all three surveys after remediation showed no improvement. This suggests that affected persons may not improve post-remediation, but new entrants to a remediated building may avoid the previous respiratory risks that students demonstrated before remediation. In our cohort study, all participants had been exposed to building conditions over the remediation period, and their experience is consistent with lack of improvement over time.

Third, is it possible that the lack of improvement in respiratory health is attributable to inadequate remediation? With the economic infeasibility of attending to the building envelope's vapor barrier, the continued water intrusion documented by consultants was not surprising. Tools to assess remediation adequacy are evolving with building science and have been hampered by the dearth of environmental measurements that correlate with health outcomes across many investigations. In this building, indications of lower proportions of hydrophilic fungi in 2005 suggested some environmental effect of remediation (data not shown), but observational indices of dampness remain a robust predictor of building-related respiratory effects [Park et al., 2004; Cox-Ganser et al., 2009]. Some investigators have reported that microbial concentrations are high during repair processes or after partial remediation [Rautiala et al., 1998; Patovirta et al., 2004; Lignell et al., 2007]. It is possible that renovation activities increase exposures associated with water damage through insufficient containment. Other researchers have also found that incomplete remediation does not lower the burden of respiratory disease [Haverinen-Shaughnessy et al., 2004, 2008; Patovirta et al., 2004; Meklin et al., 2005; Lignell et al., 2007]. For example, Haverinen-Shaughnessy et al. [2008] reported that health status of occupants of a school building remained similar or even deteriorated over a 3-year period of remediation. Our study adds to the literature that partial remediation is ineffective in curbing building-related respiratory disease, at least among occupants present in the building prior to remediation efforts, economically infeasible is important for protecting occupant respiratory health and curbing remediation expenditures. Identification of respiratory health outcomes should prompt consideration of relocating all employees to prevent incident cases during remediation. Above all, primary prevention of dampness in office buildings is critical, as ongoing remediation appears to have been of no meaningful benefit for this particular cohort.

In conclusion, the present study contributes to the evolving literature on health-related effectiveness of ongoing remediation in water-damaged buildings. We found no overall change in respiratory health and pulmonary function from 2002 to 2005 among an office employee cohort working in a building with ongoing incomplete remediation. The incident asthma and HP cases among the 97 participants are sentinel events for a continued disease risk among the larger group of employees. The only factor that appeared to improve health indices over the 3-year interval was relocation within the building, probably due to microenvironments within the building and over time. We found that symptomatic individuals and those with abnormal lung function tests were more likely to leave employment. Future longitudinal intervention studies, incorporating building science assessment and attention to both individual exposures and health, are needed to answer the question what remediation, if any, is sufficient to decrease adverse respiratory health outcomes in those already affected. Since sensitized participants (like those who developed asthma and HP) may develop symptoms in response to lower exposures than those without previous sensitization, such employees should be relocated to a dry building or dry parts of the building away from remediation activities. Study of new employees without historical exposures may be required in assessing remediation effectiveness.

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